

## **Indicator: Land Cover (324)**

Land cover is the ecological and physical structure of vegetation (or other materials where vegetation is non-existent) on the land surface. Land cover is also often described as what can be seen on land when viewed from above. Land cover represents one means to categorize landscape patterns and characteristics, which are important in understanding the dispersion and effects of chemicals and other pollutants in and on the environment. For the purposes of this indicator, land cover is described in terms of six major classes: forestland, grassland, shrubland, developed land, agricultural land, and other (includes ice/snow, bare rock, quarries/mines, and “transitional” areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities such as clearcuts or fire). Water acreages are noted, but are discussed elsewhere in this report. Developed and agricultural land trends and details are discussed under the “Land Use” indicator, while forestland details are included in the “Forest Extent and Type” indicator.

In 1992, several federal agencies agreed to operate as a consortium - known as the Multi-Resolution Land Characteristics (MRLC) Consortium, to acquire and analyze satellite-based remotely sensed data for environmental monitoring programs ([http://www.mrlc.gov/mrlc2k\\_partners.asp](http://www.mrlc.gov/mrlc2k_partners.asp)). The initial result of the MRLC was development of the 1992 National Land Cover Database (NLCD), which is the only synoptic recent classification of land cover in the continental United States.

This indicator represents data from the 1992 NLCD and the U.S. Forest Service Forest Inventory Analysis (FIA). The 1992 NLCD provides a synoptic classification of land cover for the U.S., but does not include Alaska and Hawaii, thereby classifying only 1.92 billion acres out of the estimated 2.3 billion acres of land in the U.S. Therefore, data from the 1992 FIA were used to provide forestland estimates in those two states (130.9 million acres). The twenty-one land cover classes created in the NLCD were aggregated into six major cover types (and water), sometimes called ecosystems (see [http://www.heinzctr.org/ecosystems/national/eco\\_ext.shtml](http://www.heinzctr.org/ecosystems/national/eco_ext.shtml)), that are discussed in this indicator.

### **What the Data Show**

Figure 324.1 shows the distribution of five major land cover types (note – this map is from the Heinz Report and combines grassland and shrubland cover types. Other options may exist for aggregating classes.) as well as major water features. The national acreages for these cover types are shown in Figure 324.2. The combination of the NLCD for the lower 48 states and FIA for forestland estimates in Alaska and Hawaii show approximately 694 million acres of forestland, 510 million acres of agricultural, 350 million acres of shrubland, and 307 million acres of grassland, and 41 million acres of developed land.

NLCD has also been summarized by EPA region as is shown in Figure 324.3. This figure depicts the variation in cover types nationwide, with forestland dominating in Regions 1, 2, 3, 4, and 10; agriculture in Regions 5 and 7; grassland in Region 8; and shrubland in Region 9. Region 6 consists of nearly equal coverage of grass, shrub, agriculture, and forestland. More than two-thirds of the grasslands in the nation are located in Regions 6 and 8, nearly two-thirds of shrublands are in Regions 6 and 9, and nearly half the forestlands in Regions 4 and 10.

Trend data for forest, developed, and agricultural lands are discussed in other indicators, using other data sets (FIA for forestland and the USDA Natural Resources Conservation Service National Resources Inventory – NRI for developed and agricultural lands). There are no trend data that specifically address grasslands and shrublands.

## Indicator Limitations

- The only land cover data that cover the entire nation at adequate resolution to support this indicator are dated (1992). The MRLC is developing a circa 2001 data base, but until this project is completed, there are no consistent, synoptic data to describe trends in land cover at the national or EPA Regional levels.
- The NLCD data do not include Alaska and Hawaii.
- FIA estimates of forestland in 1992 are nearly 8 percent above NLCD, NRI estimates for developed land are 110 percent above NLCD, and NRI estimates for agriculture land are less than 1 percent below NLCD. There is more variation in a data set comparison at the regional level, with FIA estimating almost 42 percent (9 million acres) more forestland in Region 9 than NLCD, NRI estimating more than 213 percent (3.7 million acres) more developed land in Region 8 than NLCD and 158 percent (8 million acres) more in Region 6, and NRI estimating 8 percent (10 million acres) less agricultural land in Region 5 than NLCD.

## Data Sources

National Land Cover Dataset (NLCD – MRLC), 1992

<http://landcover.usgs.gov/natl/landcover.asp>

USDA, U.S. Forest Service 1992 Resources Planning Act, Forest Inventory Analysis (FIA)

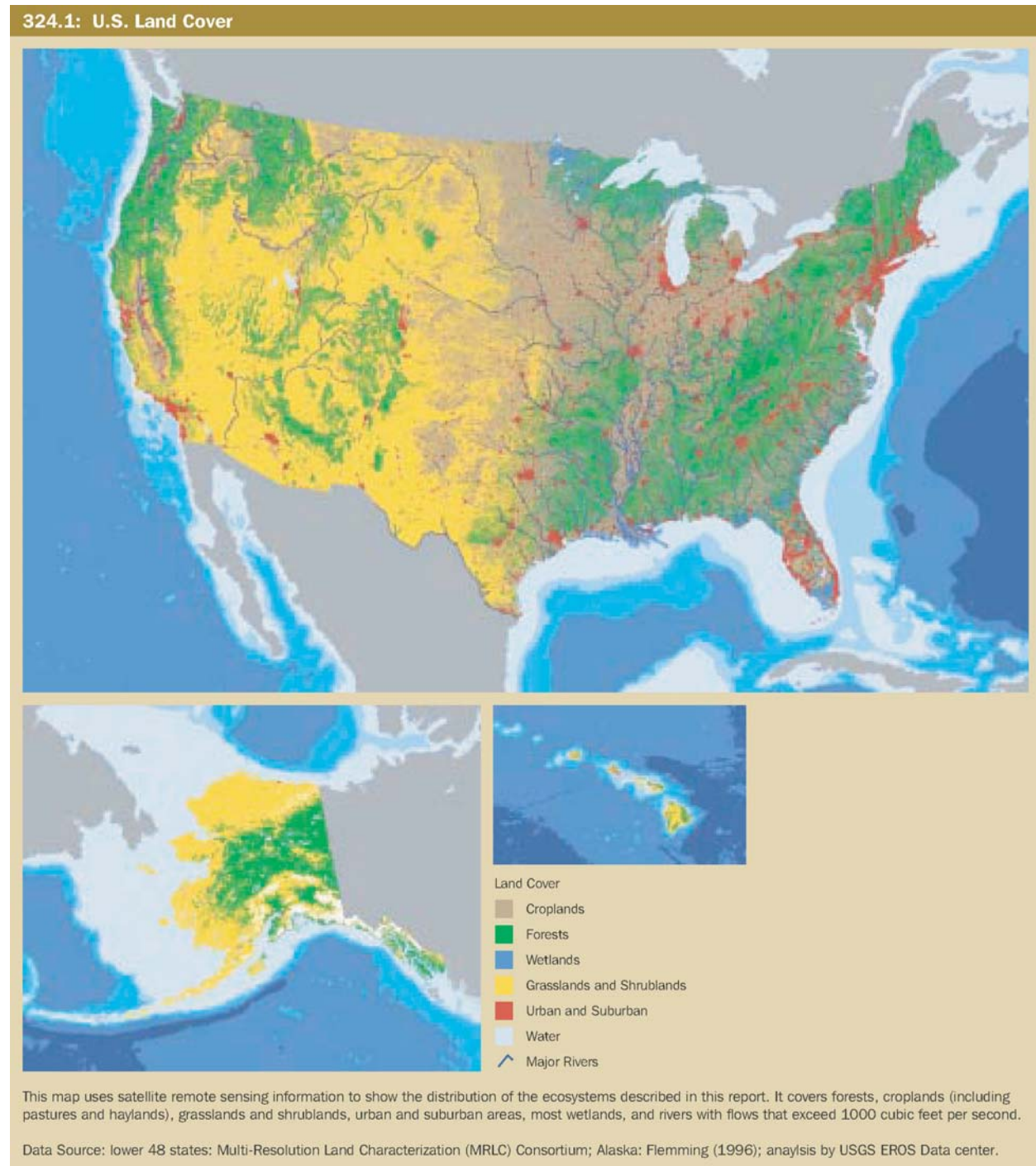
[http://www.fs.fed.us/rm/pubs\\_rm/rm\\_gtr234/rm\\_gtr234\\_02.pdf](http://www.fs.fed.us/rm/pubs_rm/rm_gtr234/rm_gtr234_02.pdf)

USDA, Natural Resources Conservation Service, National Resources Inventory (NRI) – 1992

<http://www.nrcs.usda.gov/technical/land/nri02>

## Graphics

**Figure 324-1: U.S. Land Cover**



**Figure 324.2: U.S. Land Cover Types**  
(In Millions of Acres Based on 1992 NLCD and FIA for HI and AK)

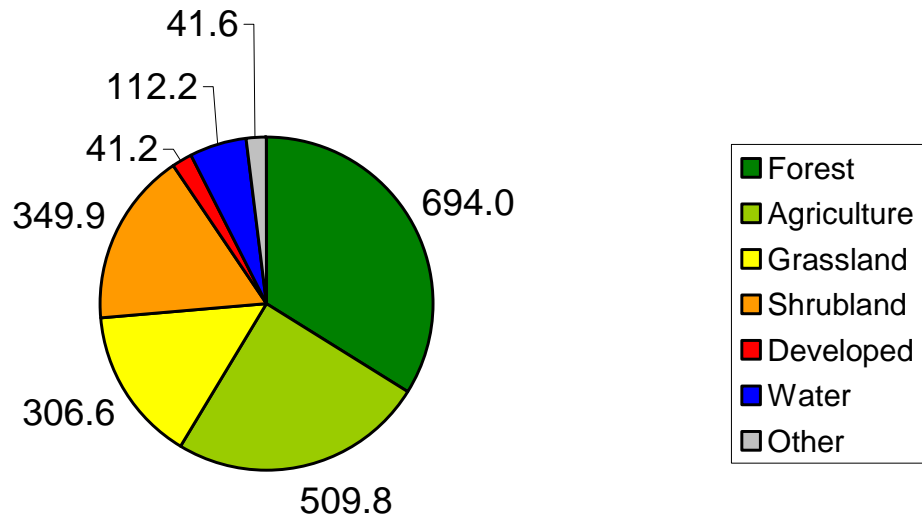
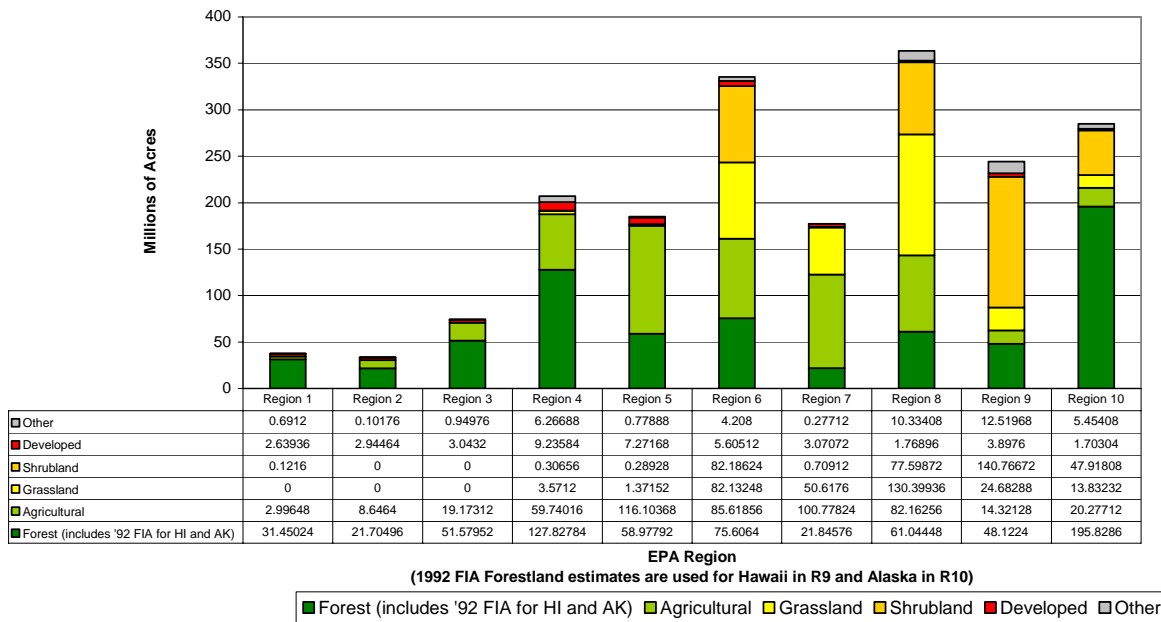


Figure 324.3: Acreage of Cover Types by EPA Region (Based on 1992 NLCD)



## R.O.E. Indicator QA/QC

**Data Set Name:** LAND COVER

**Indicator Number:** 324 (89167)

**Data Set Source:** NLCD (described herein), NRI (see #325), FIA (see #108)

**Data Collection Date:** 1992

**Data Collection Frequency:** infrequent

**Data Set Description:** Land Cover Extent

**Primary ROE Question:** What are the trends in land cover and their effects on human health and the environment

## Question/Response

**T1Q1** Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The NLCD 1992 categorizes all land in the conterminous United States by land cover type, providing a snapshot of land cover acreage. (Alaska and Hawaii are not classified). Land cover acreage is available by state and EPA region, allowing for

analysis of state and regional differences throughout the country.

<http://landcover.usgs.gov/accuracy/index.asp#methods> The FIA and NRI data are described under the Land Use Trends Indicator and are both widely accepted as scientifically and technically valid. They are compliant with standards established by the Federal Geographic Data Committee, a 19 member interagency committee composed of representatives from the Executive Office of the President, Cabinet-level and independent agencies. The FGDC is developing the National Spatial Data Infrastructure (NSDI) in cooperation with organizations from State, local and tribal governments, the academic community, and the private sector. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data

**T1Q2** Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

The data are an inventory derived from early to mid-1990s Landsat Thematic Mapper satellite data, and yield a 21-class land cover classification scheme applied consistently over the United States. Land was classified into 21 land cover types using a specific procedure, and generated estimates at the national, regional, and state level. The general NLCD procedure was to: (1) mosaic sub-regional TM scenes and classify them using an unsupervised clustering algorithm, (2) interpret and label the clusters/classes using aerial photographs as reference data, (3) resolve the labeling of confused clusters/classes using the appropriate ancillary data source(s), and (4) incorporate land cover information from other data sets and perform manual edits to augment and refine the "basic" classification developed above. The spatial resolution of the data is 30 meters. Data went through extensive accuracy assessment. <http://landcover.usgs.gov/accuracy/index.asp#methods>

**T1Q3** Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

There is no conceptual model to transfer these data to an indicator. The indicator consists of the statistics generated from the NLCD.

**T2Q1** To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

The NLCD was developed specifically to produce a consistent and seamless National Land Cover Data set (NLCD) for the conterminous United States (<http://landcover.usgs.gov/accuracy/index.asp>). The data are not a sample. Imagery exists for the entire nation, except for Alaska and Hawaii. The NLCD is not available to establish trends as the indicator calls for. Future processing of imagery will greatly enhance the value of the data to support the indicator. NLCD 2001 is currently under development, and will provide an updated assessment of land cover status in the United States, and will include Hawaii, Mexico, and Puerto Rico.

**T2Q2** To what extent does the sampling design represent sensitive populations or ecosystems?

Not applicable.

**T2Q3** Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

The NLCD is a one-time assessment of land cover status in the United States. An updated NLCD dataset will allow for a comparison of land cover estimates, and the ability to establish trends. The status of the 2001 NLCD ([http://www.mrlc.gov/nlcd\\_overall\\_status.asp](http://www.mrlc.gov/nlcd_overall_status.asp)) is available online. Until that time, threshold values or reference points cannot be established.

**T3Q1** What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Extensive documentation is available on the sampling and analytical procedures used in the NLCD on the USGS/MRLC website. [http://landcover.usgs.gov/mapping\\_proc.asp](http://landcover.usgs.gov/mapping_proc.asp) Peer reviews of the dataset also provide good summaries of the procedures involved in developing the NLCD data set, including: Vogelmann, J.E., S.M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and J. N. Van Driel, 2001, Completion of the 1990 s National Land Cover Data Set for the conterminous United States, Photogrammetric Engineering and Remote Sensing 67:650-662. The study and analytical procedures involved in the 2001 NLCD dataset can be found online ([http://www.mrlc.gov/pdfs/July\\_PERS.pdf](http://www.mrlc.gov/pdfs/July_PERS.pdf)), as well in peer reviewed articles such as the one below. Vogelmann, J.E. and Wickham, J., 2000, Implementation strategy for production of national land cover data (NLCD) from the Landsat 7 Thematic Mapper Satellite, EPA/600/R-00/051 (NTIS PB2001-101756), Las Vegas, NV.: U.S. EPA.

**T3Q2** Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

Yes. The NLCD are provided on a state-by-state basis, with state data sets cut out from larger "regional" data sets that are mosaics of Landsat TM scenes. At this time, all of the NLCD state files are available for free download as 8-bit binary files and some states are also available on CD-ROM as a Geo-TIFF. Each state data set can be downloaded, as well as FGDC metadata, from the USGS website. <http://edc2.usgs.gov/scripts/mapserv.exe?map=d%3A%5Cinetpub%5Cwwwroot%5Clerc%5Cnlcd%5Cnlcd.map&zoomsize=2> NLCD land cover class definitions are also available on the NLCD website (<http://landcover.usgs.gov/classes.asp>) A summation of NLCD metadata is available online as well. [http://mcmweb.er.usgs.gov/tnm\\_metadata/USGS\\_NLCD\\_metadata.html](http://mcmweb.er.usgs.gov/tnm_metadata/USGS_NLCD_metadata.html)

**T3Q3** Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes, the study design is clear and complete, and with adequate access to MRLC data sources, could be reproduced.

**T3Q4** To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

QA/QC of NLCD data can easily be found on the NLCD website (<http://landcover.usgs.gov/accuracy/index.asp>), as well as numerous other sources. The accuracy assessment of NLCD is achieved with: 1) a probability (two-stage cluster) sampling design; 2) a response design for reference data evaluation; and 3) an analysis procedure for estimation of accuracy parameters.

**T4Q1** Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Data collection for NLCD is based on an inventory of satellite imagery, not by sampling. As it is based on a one-time inventory of land cover in the lower 48 states, generalization beyond time or spatial locations cannot be made.

**T4Q2** Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Accuracy results are reported using several definitions of agreement between the map and primary or alternate reference land cover labels. EPA conducted an accuracy assessment for the 1992 NLCD regions and classifications (<http://www.epa.gov/mrlc/accuracy.html>). An accuracy assessment is done on all NLCD on a Federal Region basis following a revision cycle that incorporates feedback from MRLC Consortium partners and affiliated users. The accuracy assessments are conducted by private sector vendors under contract to the USEPA. A protocol has been established by the USGS and USEPA that incorporates a two-stage, geographically stratified cluster sampling plan (Zhu et al., 1999) utilizing National Aerial Photography Program (NAPP) photographs as the sampling frame and the basic sampling unit. In this design a NAPP photograph is defined as a 1st stage or primary sampling unit (PSU), and a sampled pixel within each PSU is treated as a 2nd stage or secondary sampling unit (SSU). PSU's are selected from a sampling grid based on NAPP flight-lines and photo centers, each grid cell measures 15' X 15' (minutes of latitude/longitude) and consists of 32 NHAP photographs. A geographically stratified random sampling is performed with 1 NAPP photo being randomly selected from each cell (geographic strata), if a sampled photo falls outside of the regional boundary it is not used. Second stage sampling is accomplished by selecting SSU's (pixels) within each PSU (NAPP photo) to provide the actual locations for the reference land cover classification. The SSU's are manually interpreted and misclassification errors are estimated and described using a traditional error matrix as well as a number of other important measures including the overall proportion of pixels correctly classified, user's and producer's accuracies, and omission and commission error probabilities.

**T4Q3** Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

At the local level, USGS/EPA have noted that data quality affects the ability to infer results or trends, stating Users are cautioned who intend to apply the data to highly localized studies, such as over a small urban-suburban setting or a watershed of only tens of square miles. The land cover data quality of such a small geographic extent is unknown and the users should carefully examine the NLCD product in the local context to determine its utility. (<http://landcover.usgs.gov/accuracy/index.asp#conclusion>)

**T4Q4** Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

The NLCD is a one-time snapshot of land cover of the United States, and is now more than 10 years old. An updated dataset is currently being created (NLCD 2001) with an anticipated completion date of 2006 or 2007, but the land cover classifications have changed slightly, as has the Landsat imagery from which the dataset is largely based (Landsat 7 vs. Landsat 5). The NLCD does not include Hawaii and Alaska. NLCD 2001 will include estimates for Hawaii and Alaska, as well as Puerto Rico.